Wolfgang Loibl (wolfgang.loibl@ait.ac.at)[1], Ghazal Etminan[1], Doris Österreicher[2], Gustav Puhr[2], Matthias Ratheiser[3], Simon Tschannett[3], Milena Vuckovic[1]
1 AIT Austrian Institute of Technology GmbH, Center for Energy, Digital Resilient Cities, Giefinggasse 6, 1210 Wien.
2 University of Natural Resources and Life Sciences, Vienna; Peter Jordanstr. 82, 1190 Wien.
3 Weatherpark GmbH, Gardegasse 3, 1070 Vienna,

CLUDEX - CLIMATE CHANGE AND URBAN DENSIFICATION IMPACT EXPLORATION

Objectives:

- CLUDEX examines urban climate changes, triggered by urban densification, assuming building height increase to height zoning limits. Meidling, an urbanized district in Vienna, serves as a study area to demonstrate these urban densification effects..
- To better cope in the future with urban density- and climate changes in urban environments, adaptation measures will be tested reducing climate impact as well as urban fabric impact:
  - extension of urban green in streets, facades, rooftop areas;
  - improved layout of open spaces, streetscapes;
  - building design.
- This will be examined through microclimate simulations applying 3D models of densification- scenarios, Finally, adaptation alternatives will be discussed with public stakeholders and the results will feed into suggestions for urban planning guidelines.

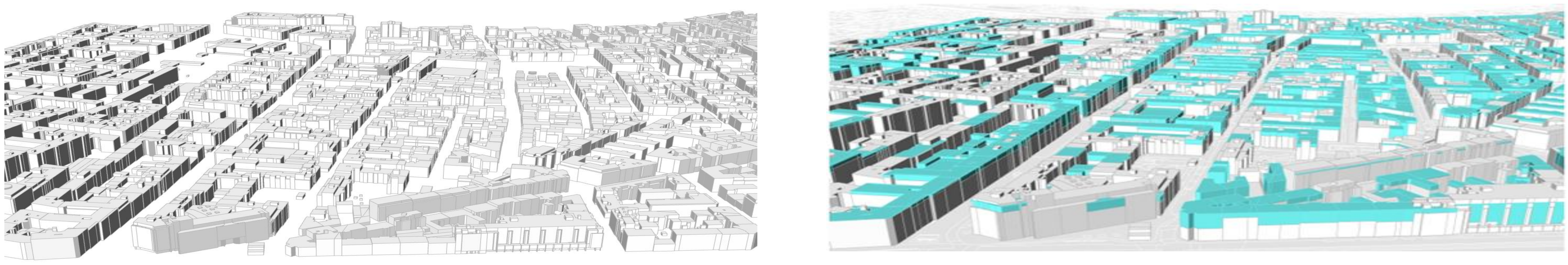

Figure 1a 1b: Current building structure and densification potential of Vienna's 12th district around Meidlinger Hauptstraße (in blue) according to the building height limits of the Vienna zoning plan. (Sources: 3D model, densification scenario processing: AIT)

METHODS

- The **building structure** is generated as 3D model by taking the buildings' footprints and extruding those to 3D objects considering the height information. An assumed average floor height of 4 m for old buildings and 3 m for new ones let estimate the current gross floorspace for housing in the study area (Fig. 1a).
- The entire **district's densification potential** is estimated, based on height zoning information. Therefore, line- and annotation layers from Vienna's planning department, are converted into a geodata set, to link building height limitation (the "Bauklasse" distribution) spatially with the current building footprints (Fig. 1b).
- **Differences between building height limits and observed building height** allow, assuming a 3 m floor height, to **estimate the additional number of floors and the gross floor space**. Additional floor space through rooftop extensions, receding towards the building's eaves, are estimated as 75% of the buildings' footprints.
- **Extreme densification** beyond actual height zoning limits have been modeled for certain areas by extruding some building footprints to 80 and 100 m to examine **local effects of individual high-rise** buildings on urban climate (Fig. 2c).
- For **test buildings** in a sample area around Meidlinger Hauptstraße it was examined how different materials for rooftop extensions (heavy weight and light weight construction), and thus different thermal masses, affect the temperature regime of the buildings' indoor climate and thus heating and cooling requirements.
- **Wind pattern analysis** has been conducted to identify the wind direction and force frequency distribution for Vienna's 12th district from existing long-term climate time series as input for wind field simulations.
- **Wind field simulations** have been carried out to model medium scale wind conditions in the study area during typical heat wave periods for current building structure and densification scenarios (overall densification and individual densification through selected high-rise buildings)
- **Microclimate simulations** allow a comprehensive assessment of heat load distribution under different climate and wind conditions using 3D models for densification scenarios. Simulation tools applied are EMVI-MET and Grasshopper/Ladybug.

RESULTS

Urban Densification scenarios:

- Taking advantage of the maximum height based on the zoning in Meidling, a substantial extension of the current building heights is possible (Figure 1b). The gross floor space (GFS) can be raised by 16 % in the residential and mixed use area. By adding apartments to rooftops, the GFS can be raised by 25% (2,8 Mill m^2), allowing to add 15 to 25% additional flats within the current building stock.
- To examine the densification impact on micro-climate, several test sites have been extracted from the 3D-models for current state and densification scenarios. Figures 1 show the entire area, Fig. 2a-d present a sample area with general densification along Meidlinger Hauptstraße and two high-rise building scenarios in the north and south of Meidlinger Hauptstraße (near U4 Station Meidling and Bahnhof Meidling).

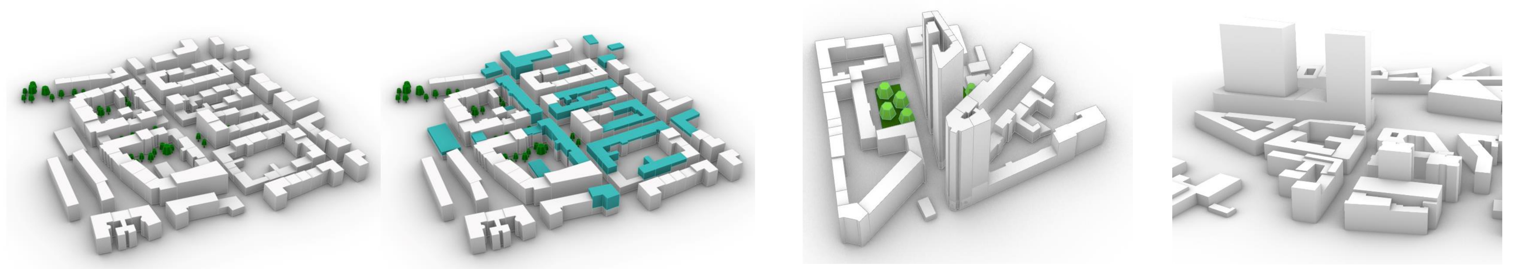

Figure 2 a-d: Current building structure (a), densification scenario (b) of the sample area (based on maximum height zoning) and for individual high-rise buildings south and north of Meidlinger Hauptstraße (c, d)

Wind:

- 30 year wind pattern analysis shows the prevailing wind direction during heat days is southeast (Fig. 3 a-b).
- Wind simulations show that a general densification declines wind speed in some areas, in few areas wind speed is increasing (Fig. 3c-d). Individual high-rise buildings are affecting wind comfort through local extreme turbulences, may lead to extreme local windspeed increase, very individual impact due to shape.

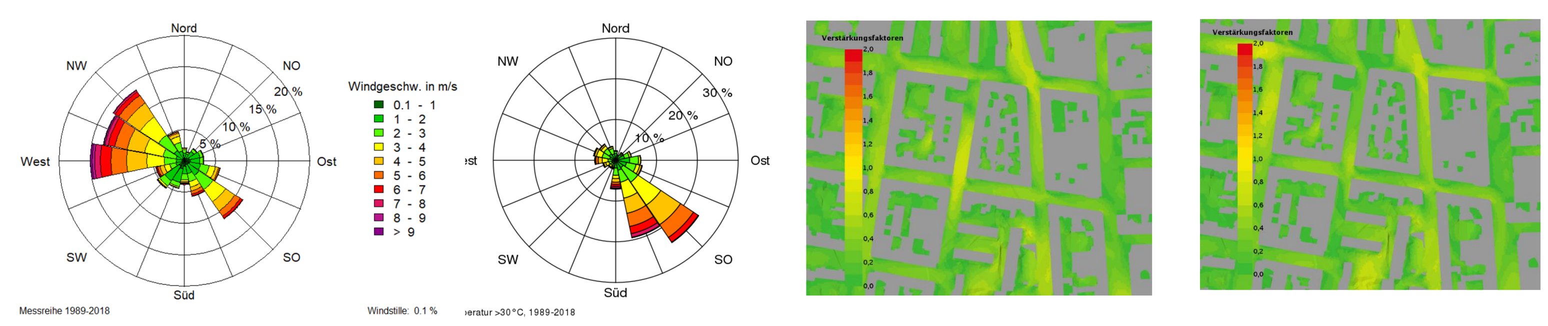

Figure 3 a-b: Wind direction and speed distribution: annual distribution (a), heat day temperature distribution: SE (b)
Figure 3 c-d: Wind speed: w/o (c) and with densification (d): yellow indicates speed increase, dark green indicates speed decline

Microclimate:

- Microclimate simulations for a certain heat wave (August 9 – 11th, 2014) allows to examine temperature differences (mean radiant temperature, MRT) through densification
- Shaded areas show cooling effects, rooftops show heating effects after densification. While densification lead to more shade during day time, day hours show less mean radiant temperature (-12°C MRT/12 hours; = ca. -1°C MRT/1hour). Night hours show little additional heat trapping effects (Fig. 4a-c). Individual high-rise buildings show MRT decrease because of the larger shaded areas (Fig. 4d-f). Decreasing windspeed (-50%) show little impact on MRT (+2°C MRT/24 hours = +0.1 °C per 1hour) (Fig. 5a-d).

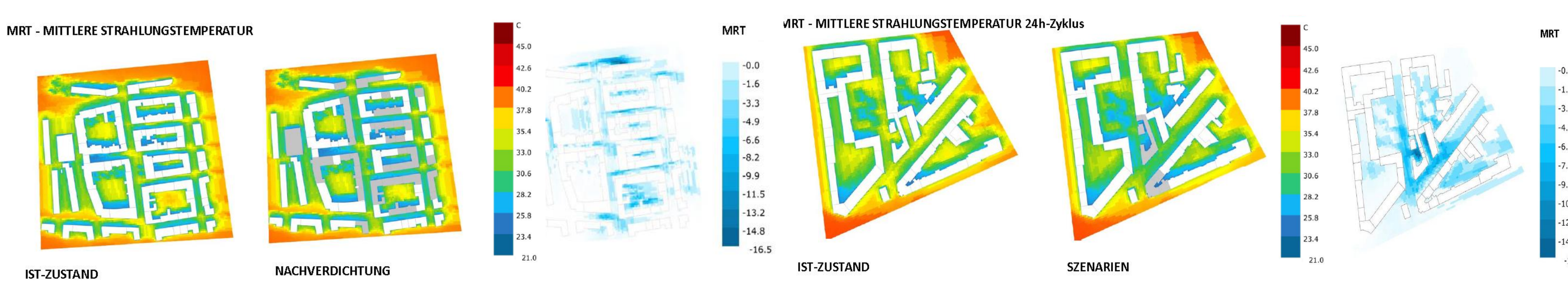

Figure 4a-e: MRT in the sample area during a hot summer day (24 hours average) w/o (c) and with densification (a,b), MRT differences (c), MRT in the southern local densification scenario– base case (d) and high rise cluster (3), MRT differences (e)

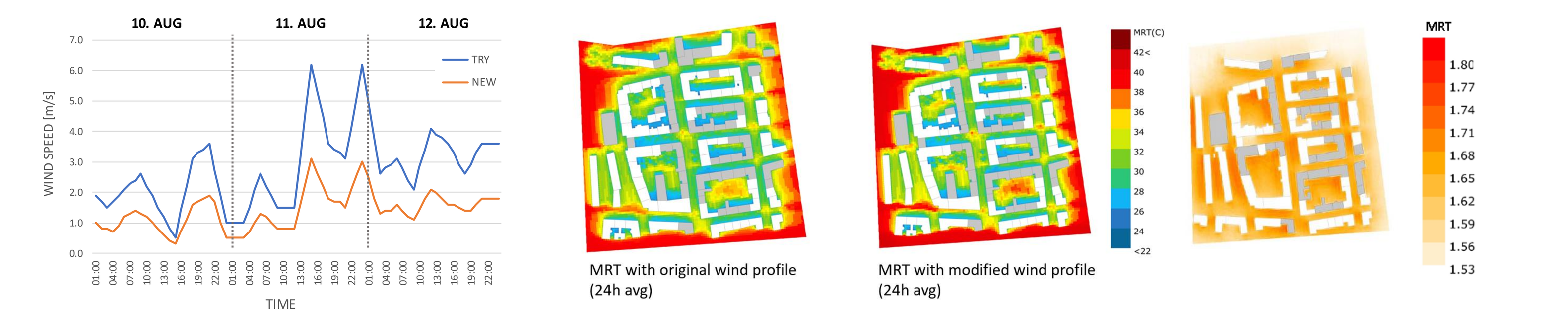

Figure 5a-d: Hourly wind speed change during a heat wave triggered by densification(a); MRT during a hot summer day (24 hours average) with original and reduced windspeed (b, c), MRT-difference in 24 hours (d)

Climate adaptation measures:

- Urban green reduces MRT near trees, at facades especially during day time: MRT decline -12 °C / 12 hours = -1°C/1hour) causing a similar effect as shading through higher buildings (Figures 6a-c, compared with Figures 4a-c).
- Rooftop greening has little effect on MRT at street level (-0.5°C/12 hours = 0,04°C/1hour) but has positive local effect at the rooftops and contribute to insulation of the flats below. (Fig. 6a,c,e)

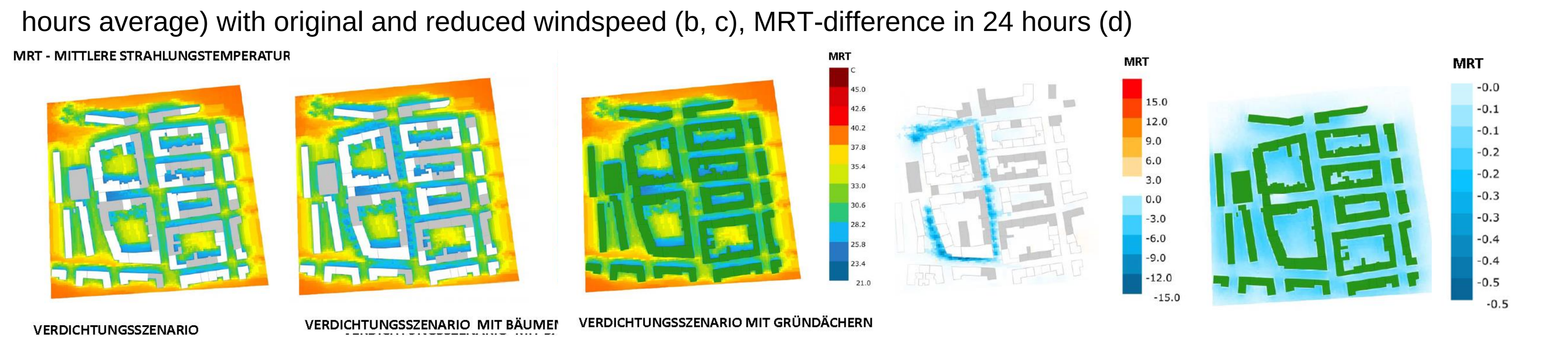

Figure 6a-c: climate adaptation measures – trees and rooftop greening supports MRT decrease (a versus b, versus c) MRT difference during daytime due to tree shading (d and due to rooftop greening.

Indoor climate simulations

- Thermal simulations for selected buildings allows to examine thermal mass influence on indoor-temperatures and thus, heating and cooling requirements. Lowest temperatures are reached with solid wood walls which have more thermal mass than lightweight wood constructions, performing even better than massive concrete. (Fig. 7 a)
- Terrace and facade greening as well as window area and shading devices have further large effects on indoor temperature regime (Fig. 7 b)

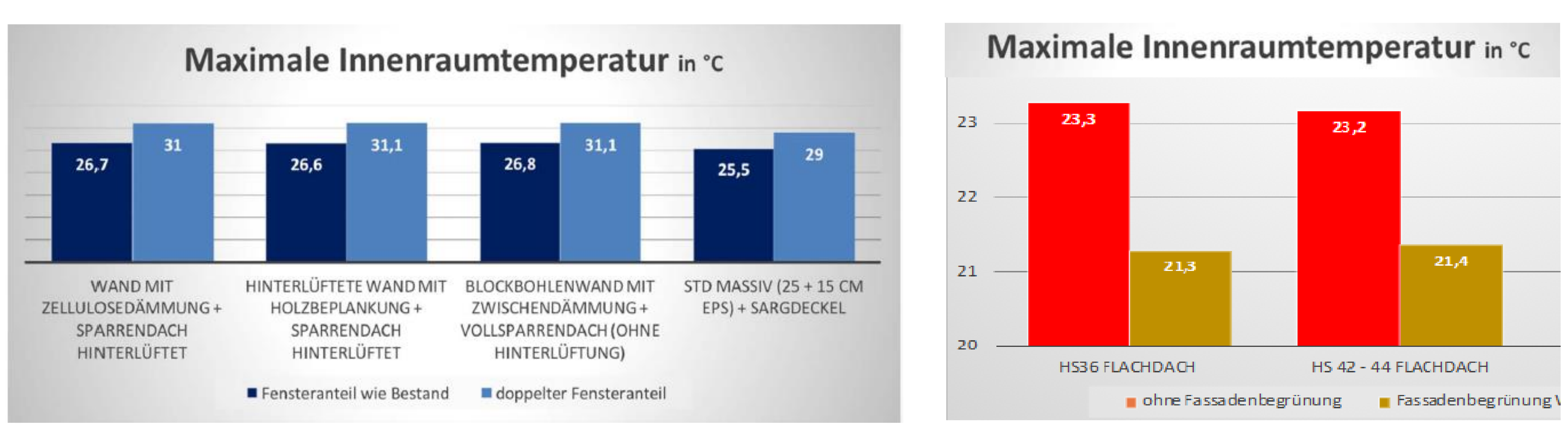

Figure 7a-b: Indoor temperature depending on construction type and window area (a); depending on facade greening(b)

Workshops on planning guidelines for urban densification facing climate change

- Stakeholders from different Vienna planning departments are involved: Environmental and Climate protection (MA22), Urban development (MA18), Urban district planning (MA21A, MA21B),
- 2 workshops have been carried out now, one with >20, one with 8 attendees. One workshop is pending due to Corona Virus protection requirements. – This shall take place during September.

Scientific output:

- Loibl, W. Etminan, G., Österreicher, D., Ratheiser, R., Stollnberger, R., Tschannett, S., Tötzer, T., Vuckovic, M., Walal, K. (2019) Urban densification and urban climate change – assessing interaction through densification scenarios and climate simulations. REAL CORP 2019 Karlsruhe, 2-4 April 2019, Karlsruhe Institute of Technology, Germany, Conference Proceedings: https://conference.corp.at/index.php?id=38&L=0
- Vuckovic, M., Loibl, W., Tötzer T., Stollnberger, R. (2019) Potential of Urban Densification to Mitigate the Effects of Heat Island in Vienna, Austria. *Environments* 2019, *6*(7), 82; https://doi.org/10.3390/environments6070082/ Published 10 July 2019
- Vuckovic; M:, Tötzer, T., Stollnberger; R. , Loibl, W. (2020) Urban transformation and heat island: Potential of urban design alternatives to mitigate the effects of urban overheating in Austrian cities. Journal or Urban Environment V1(2020). pp 3-14 https://www.euraass.com/jue/Volume1/Issue1/Volume1Issue1-JUE-2020-0002.html
- W. Loibl, W., Vuckovic, M., Etminan, G., Ratheiser, M., Tschannet, S., Österreicher, D. (2020). Effects of Densification on Urban Microclimate - A Case Study for the City of Vienna; in preparation, to be submitted to Atmosphere